COMPOUND INJURIES OF THE KNEE JOINT*

STUDY I—TREATMENT OF NONINFECTED KNEE JOINTS

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DURING THE TWO AND ONE-HALF YEARS in which the armed forces were engaged in active warfare, first in the Mediterranean Theater and later in the European Theater, many well-crystallized ideas about the surgical management of the wounded were developed. The program of early re reparative surgery, as envisioned by Colonel E. D. Churchill, is, without doubt, one of the major contributions to come from the present conflict.

The surgery of wounds of the knee joint is an outstanding example of a field where clear, concise ideas of the proper type of surgical care have evolved. The early care of these penetrating and perforating injuries is now well-standardized. The joint must be opened widely and explored in order to remove all destroyed and devitalized cartilage and bone. The synovium is then closed, and penicillin is instilled into the joint. The skin is left open in the Forward Hospitals.

The Office of the Surgeon-General has recognized the need for early, thorough exploration of compound injuries of the knee. Technical Bulletin No. 147, published in March, 1945, states: "The wound of the soft-part is excised and the bone and cartilage damage assessed through incisions that provide complete exposure. Comminuted fragments of bone and cartilage are removed from the joint and a careful search made for foreign material." Thompson, Cassebaum, and Stewart recorded the experiences of an Evacuation Hospital in treating war wounds of the knee. Their observations were based on 172 penetrating injuries of the knee, 131 of which were subjected to formal, exploratory arthrotomy. We received many of these patients and know that the results were excellent.

With the accepted, early treatment of knee injuries by exploratory arthrotomy, the patient is given the best opportunity to escape the consequences of a suppurative arthritis. Furthermore, the later function of the joint is best assured by the early removal of all loose and foreign bodies. It should be emphasized that the after care of these wounds is very important. Much of the future function depends on the proper management of such patients at the Base Hospitals. Assuming that the knee wound has been cared for primarily in the Forward Hospital, the wounded man is usually transportable to the Fixed Hospitals after the effects of the anesthetic have worn off. Actually, he reaches the Base any time between the second and eighth day after wounding. The authors were concerned with the after care of these patients in the Base Hospital.

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During the 35 months spent in Africa, Italy and France,* over 300 compound injuries of the knee joint were seen and treated. Accurate statistics are available on 244 cases seen in Italy and France. Almost all these patients had received their primary care in the Evacuation Hospital.

**Historical.**—During the early part of the African campaign, the lines of evacuation were long and complicated, so that the majority of the patients were seen late after wounding. By the time the occasional patient with an infected knee joint reached the Base, a pyarthrosis had already developed. Unfortunately, no accurate figures are available on the penetrating wounds seen during the African campaign. In general, however, the initial surgery on penetrating wounds of the knee joint during this campaign consisted of the débridement of the wound, removal of the foreign body, and closure of the synovium. Some hospitals elected formal, exploratory arthrotomies, with closure of the synovium, even at this early date, but our records are too inadequate to draw any conclusions about the surgical principles employed in the Forward Hospitals. At the General Hospitals, the advantages of secondary suture of wounds were just being realized, and few knee wounds were actually sutured.

Septic joints with pyarthrosis were treated by bipatella incision, removal of the foreign body, irrigation of the joint space, and immobilization in a plaster hip spica. The synovium was held open by a pack which extended to, but not into, the joint. These patients usually had a stormy course and showed weight loss and other signs of chronic suppuration.

During the Italian campaign the management of wounds was changed radically. The program of secondary suture proved to be basically sound. Revolutionary advances were made in the management of soft-tissue injuries, but even greater was the advance in the methods of handling wounds of the knee joint. Whereas treatment of wounds early in the war was passive, and consisted principally of immobilization in plaster to avoid spreading infection, the program in Italy was changed to an active one, designed to control and eliminate infection and to restore function as early as possible. In the care of knee injuries, the early restoration of function is particularly important in order to avoid muscle atrophy and joint adhesions.

During the months of static warfare on the Cassino front in Italy, the Forward Hospitals reached a degree of excellence in the performance of débridements that has not since, in our opinion, been duplicated. The clean surgical wounds seen at the Base were most suitable for closure, and the entire program was facilitated. The value of routine, early arthrotomy became evident, but the procedure was not universally accepted during the early part of the Italian campaign.

The widespread use of penicillin as an aid in combating wound infection dates from the Spring of 1944. With the introduction of this new chemotherapeutic agent, the approach to reparative care of all types of wounded became

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* The 21st General Hospital operated in North Africa from January to November, 1943, in Italy from January to September, 1944, and in France from October, 1944, until September, 1945.
more active. The conservative attitude toward treatment of knee joints with complicating infection changed to a more aggressive surgical approach. This viewpoint will be presented in Study II, based on this same series of 244 cases. The present paper is concerned with the early care of uninfected compound injuries of the knee joint. Although the conclusions are based on experience with battle injuries of the knee, they are also applicable to injuries of the knee seen in civilian surgery.

**Care of Joint Injuries at the Base Hospital.**—When received from the Forward Hospital, the patient with an adequately treated wound of the knee is comfortable, although he may have some fever if the period since wounding is short. He has had the benefit of arthrotomy, the joint has been débrided, the synovium closed, penicillin injected locally, the wound dressed, and the extremity immobilized in a long leg plaster encasement or Tobruk splint. A hip spica is preferred in the presence of severe bone injury. After correction of secondary anemia, and with the continuation of parenteral penicillin therapy, the patient is taken to the operating room, where facilities are available for formal arthrotomy. The plaster and dressings over the wound are removed. It is important that the original dressing should not be changed until this time, as repeated dressing of the wound leads only to secondary contamination and suppuration. If penicillin is instilled repeatedly at the Forward Hospital, it should be done without disturbing the dressings over the wound proper. After removal of the dressings in the operating room, the knee is inspected and tested for increased fluid, and most important, tested for pain on motion of the joint. The patient must necessarily remain awake during this portion of the procedure. The uninfected knee will have a small range of painless motion, whereas the infected knee joint is painful to even minor degrees of motion. It must be pointed out, however, that excessive ranges of motion, even in uninfected joints, will be painful. The patient is then anesthetized. If fluid is present, the joint is aspirated, the fluid examined grossly, and specimens taken for smear and culture. Gentle irrigation with saline through the aspiration needle is performed and the character of the returning fluid is carefully noted. The infected joint with leaking synovium will be apt to discharge flecks of purulent material with the irrigating fluid. If definite indication for arthrotomy exists, it should be done without delay, and with the aid of a pneumatic cuff tourniquet in order that the visualization of the joint be unimpaired. Usually, the joint which has received proper care in the forward area will need no further intra-articular surgery. Ten or twenty thousand units of penicillin in 10 to 20 cc. of saline are instilled into the synovial cavity. The skin, left unsutured in the Forward Hospital, is closed by simple suture. Systemic penicillin consisting of 25,000 units every three hours is continued from the time of admission to the Base until the knee wound is healed.

**Immobilization.**—The ordinary uncomplicated knee injury is usually immobilized in extension in a Tobruk splint. The principle of traction as well as immobilization is utilized by this type of splinting. Suppurating knee joints are immobilized in plaster hip spicas. However, it would seem that the type of
immobilization is not as important as the operative procedure in attempting to
arrest the suppurative process within the joint. The real victories over infected
joints rest in thorough exploration of the joint and removal of the cause or
causes for suppuration.

The uncomplicated knee joint may require a second local instillation of
penicillin, but usually the single instillation at the time of secondary suture is
considered adequate. If indication for other injections arises, these may be
done through a window in the encasement. The ordinary case without severe
fracture is immobilized for about five to seven days after operation at the Base.
Those cases where complication has occurred should receive daily local instilla-
tions of penicillin until the effusion has subsided and the temperature is reced-
ing. The systemic use of penicillin is continued also. Cases which respond
favorably will generally show marked improvement in two or three days, the
effusion subsiding gradually. The amount of periarticular swelling is sometimes
surprising and becomes evident as joint effusion disappears. In the absence of
major bone or soft-tissue damage, the plaster encasement is removed and
gentle motion is started a few days after symptoms have subsided. No immo-
ibilization is used thereafter.

There is a minimal period during which the patient with a wound of the
knee joint should be followed at the Base, and during which he should be
considered nontransportable. This period is about three weeks in the average
case. During this time, the skin should be closed, and quadriceps exercises and
motion of the knee started. Evidence of suppuration or other complication,
such as serious quadriceps atrophy or delay in moving the joint, is sufficient
indication to prolong hospitalization in order to explore the knee or to super-
vise rehabilitation.

The keynotes in the after care of clean wounds of the knee are: First, the
initiation of proper exercises as early as the first day after secondary suture of
the skin to prevent quadriceps atrophy; and, second, the early mobilization
of the joint to prevent the formation of adhesions that would restrict the
range of motion. The latter is very important where the synovium has been
destroyed at its lateral and medial reflections. For these reasons, the thorough-
ness of the initial care, aimed at preventing suppuration and smoothing artic-
ular defects, is probably the one most important phase in the proper care of
compound injuries of the knee. It is only in those knee joints that have been
properly cared for in the Evacuation Hospitals that early motion can be
instituted.

Incidence of Complicating Fractures.—Bone injury was recorded in 168
of the 244 penetrating and perforating injuries of the knee. Forty-four of the
entire series, or 18 per cent, were severe comminuted fractures of one or more
condyles. Fracture of the patella occurred in 49 of the 244 cases, an incidence
of 20 per cent. Thirteen of the series of 49 fractured patellae had had primary
excision of the patella in the Forward Hospital. One patient had had partial
excision of the patella at the Evacuation Hospital. At the time of reparative
surgery, three more of the fractured patellae were excised, and the above men-
tioned partial patellectomy was completed.

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COMPOUND INJURIES OF KNEE JOINT

Table I

<table>
<thead>
<tr>
<th>Description</th>
<th>No. of Cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total compound injuries of the knee joint</td>
<td>244</td>
<td>100</td>
</tr>
<tr>
<td>Total number of wounded, with bony injury</td>
<td>168</td>
<td>67</td>
</tr>
<tr>
<td>Total number with severe comminuted fractures</td>
<td>44</td>
<td>18</td>
</tr>
<tr>
<td>Total fractures of the patella</td>
<td>49</td>
<td>20</td>
</tr>
<tr>
<td>Fractures of the patella treated by primary excision</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Fractures of the patella treated by secondary excision</td>
<td>4 (1 exc. comp.)</td>
<td></td>
</tr>
<tr>
<td>Total fractures treated by patellectomy</td>
<td>17</td>
<td>7</td>
</tr>
</tbody>
</table>

Severely comminuted fractures of the patella with irregularity of the articular surface should be treated by total patellectomy in order to minimize the later development of traumatic arthritis and to prevent infection. If a major fragment of the patella remains as a single piece with good articular surface, it may be possible to leave this segment in place, after removing the comminuted fragments. This may then be secured to the ligaments by wire sutures, if necessary. Experiments by Cohn indicate that total patellectomy is to be avoided when possible. The patella or portion of the patella is left only when the under surface of the part remaining is perfectly smooth. Many fractures of the patella are incomplete. Curettage of the fractured area and débridement of the injured tissue about it may leave almost the entire articular surface of the patella intact. Infected comminuted bits of the patella were curetted in four of the 49 fractures in this series.

If the roentgenograms are not decisive, the under surface of the patella should be felt with the gloved finger at the time of reparative surgery or secondary suture. This is to be done even at the risk of contaminating the joint by going through the wound to reach it.

In a large majority of cases, bone injury to the condyles is minor in nature, consisting of either penetrating injuries of bone, chip fractures, or incomplete fractures. On the other hand, the seriousness of the injury is not to be minimized in view of the danger of suppuration in the joint. The usual injury involves either the medial or lateral condyle of the femur, because the surface exposed is much greater. At arthrotomy, with adequate exposure, the irregular defect in the condyle is evident. The foreign body may project above the surface, embedded in the bone, or the elastic articular cartilage may close over the defect and hide the missile. In every instance, the missile should be removed when operative removal is not difficult. Sometimes, the missile will have passed up into the marrow cavity and usually it does not reflect good judgment to attempt recovery in such cases. After extraction of the metal, the edges of the defect are irregular and must be thoroughly smoothed and trimmed. Loose pieces of articular cartilage may interfere with the future function by doubling outward into the joint to become trapped between the tibial and femoral condyles. It is very important for future function as well as for the control of early infection, that the joint be inspected for loose particles. The defect in the condyle should be carefully prepared so that the edges are smooth and no tags of cartilage remain.

The severely comminuted fracture of the knee presents a serious problem at times. These wounds may be produced by either bullets or shell fragments.
The outlook is more serious in the latter. None of the four bullet wounds of the knee with marked degree of comminution developed a suppurating joint. There were 35 severely comminuted fractures secondary to wounding by shell fragments, and of this number, 12 patients developed uncontrolled infections of the knee joint. If the joint does not become infected, one can either use skeletal traction to avoid shortening of the extremity, or immobilize the joint in plaster hip spica to await solidification of the fragments. The shattered joint with irregular surface will probably require fusion at some later time.

The joint that is open as a result of the loss of soft-parts is also a serious problem. If the soft-parts are avulsed to such an extent that the joint cannot be closed, there is usually bone loss as well, and saving the joint is useless. If, however, there is loss of soft-parts with preservation of the bony and cartilaginous structures, prevention of infection is desirable, and a plastic procedure should be tried in order to try to close the joint space. In ten cases of the present series, there was loss of soft-tissues to such an extent that closure of the joint by simple suture was not possible. In five of the ten cases plastic closure was attempted. (The remaining five cases were damaged beyond repair.) This can be done either by swinging a wide-base pedicle flap over the soft-tissue defect of the joint, or by undercutting a bridge of skin, leaving it attached at both ends and advancing it over the defect. In two cases of the five the results were excellent and infection, otherwise inevitable, was avoided. A third patient had some drainage from beneath the flap which was thought to be from an osteomyelitis of the femoral condyle. He was afebrile when evacuated and his final result is not known at this time. Two cases must be regarded as failures, as both joints continued to drain along the borders of the flap. Flap closure is certainly to be tried in all those cases where enough of the bony parts remain to warrant an attempt to save the articulation. Such flap procedures are probably best done in the Forward Hospitals at the time of débridement. The delay in reaching definitive surgery is sometimes so great that irreparable damage is done to exposed articular surfaces before the joint is converted into a closed cavity.

The Italian and French campaigns have afforded an excellent opportunity to study the merits of routine early arthrotomy. During the early phase of the Italian campaign, 99 compound injuries of the knee joint were treated. Of these 99, only 32 had been subjected to formal arthrotomy at the time of initial care. In 60 cases, either débridement alone had been done, or, in some few cases, the foreign body had been considered small enough to leave in, or adjacent to, the joint. The records in the remaining seven patients are not clear.

With the invasion of Southern France, Colonel F. B. Berry, consulting surgeon to the 7th Army, directed that all wounds of the knee joint be subjected to formal arthrotomy. This directive was based on the experiences gained in Italy. The improvement in results was striking. One hundred and forty-five compound injuries of the knee were treated in France. Ninety-five of these had been subjected to complete exploration of the joint. The records in six other patients were inadequate. Forty-three patients had not been subjected to formal arthrotomy. (As patients reached us from other than the 7th
Army, the incidence of wounds débrided without arthrotomy increased.) The incidence of suppurating knee joints in the Italian series was about 16 per cent. In the French series, the over-all incidence was 9.6 per cent. However, the significant difference rests in those cases which were found to be septic on admission and which were amenable to secondary débridement of the joint. Of the 15 cases subjected to secondary arthrotomy as described in Part II, 12 were in the Italian series. Eleven of the 12 had not been subjected to formal arthrotomy in the Evacuation Hospitals. Of the three septic cases seen in France, and thought to be operable, all had been given the benefit of formal arthrotomy as part of the primary care. The reason for suppuration in these three cases was believed to be inadequate surgery. Suppuration in those joints with relatively minor cartilaginous and bony damage if left unchecked, is a much greater catastrophe than suppuration in a joint which will probably be nonfunctional due to severe fracture and irregularity of the joint surfaces. The significant difference between the series of routine, early arthrotomy and that of débridement of the soft-parts or simple removal of the foreign body lies in the reduced rate of infection in those cases where bony damage is minor and where preservation of a functioning joint is assured if infection can be circumvented.

Finally, a word should be said about the wounding agent. Table II shows the relative percentage in the present series:

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Wounded by shell fragment</td>
<td>188</td>
<td>77</td>
</tr>
<tr>
<td>Wounded by small arms</td>
<td>44</td>
<td>18</td>
</tr>
<tr>
<td>Wounded by questionable agent</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

It is significant that 27 of the 28 knees that were septic on admission were the result of shell fragment wounds. The one septic bullet wound in the series as shown in the last table of Study II, is open to question. One must logically conclude that the highly shattered knee joint caused by a bullet wound should be treated conservatively, since the probability is that the joint will not become infected. On the other hand, the minor degrees of bone injury secondary to bullet wound require arthrotomy, not so much to avoid infection as to assure later function of the joint by removing loose and partially detached bone and cartilage from the joint.

**SUMMARY AND CONCLUSIONS**

1. Results of the surgical care of 244 compound injuries of the knee joint are presented.
2. The history of the evolution of a standardized program of reparative surgery in these cases is given.
3. Details of the surgical approach to the noninfected wound of the knee joint are outlined, with stress on the local and general use of penicillin.
4. The importance of the detection of early suppurative arthritis of the knee should be emphasized and the value of the diagnostic sign of pain on motion of the injured knee is stressed.
5. Early mobilization of these injuries is necessary in order to prevent joint and quadriceps atrophy, as well as restricted motion.

6. The high incidence of patellectomy in this series (35 per cent of patella fractures) is thought to be justified in view of the possibility of subsequent infection or traumatic arthritis.

7. The lowered incidence of sepsis treated in this hospital during the French campaign is believed to be convincing evidence of the value of the surgical program outlined.

REFERENCES


(To be continued)